Partial Discharges using Variable Frequency PRPDA Technique

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***Abstract*—At the applied voltage a disc-shaped cavity with partial discharges are measured at variable frequency (0.01-50 Hz). By varying the frequency it was observed that measured PD phase, magnitude of distributions and number of PDs per voltage cycles are varied. In the cavity, sequence of Partial discharge is simulated dynamically. For that purpose a model is presented with charge consistent. Simulated results shows that cavity surface and emission properties are effected by varying the magnitude of applied frequency, mainly conductivity of surface. This paper is illustrating the frequency dependence of PD in a cavity. The paper illustrates how the applied voltage amplitude and the cavity size can influence the frequency dependence PD activity.**

Keywords: Partial discharges, simulation, modeling, variable frequency, cavities, disc-shaped and epoxy resin.

I. INTRODUCTION

Insulation is a major portion of the high voltage equipment. Numerous forms of insulating materials are used in high voltage electrical power system. The property of insulating material deteriorates enormously with the effect of partial discharge. Therefore, to keep the high voltage power equipment in healthy condition and to ensure the reliability of the power system the detection of partial discharge measurement is very important. Partial discharge occurs due to the defects in insulation system. Partial discharge results only if the electric field in the defects exceeds the thresh-hold field. The partial discharges are of different types e.g surface, internal and corona discharge. Partial discharge can occur in all medium of insulations due to presence of voids, cavities, gas bubbles in insulation. Sharp edges in insulation are one of the major sources of partial discharge (PD). For the detection and measurement of partial discharge in electrical insulation, variable frequency phase resolved partial discharge analysis is used [1, 2].

The main objective of measurement and detection partial discharge using different frequency is to decrease the size and power of the supply equipment. Though the power frequency greater than normal frequency is too important [3]. It has been observed that with increasing applied frequency the apparent charge per cycle of the applied voltage is decreased. Nowadays partial discharge activity in high voltage equipment is measured and detected using different voltage frequencies to ensure the reliability of power system. Recent studies [1, 5] have been used for comparing partial discharge measurement results obtained with different methods to analyze partial discharge behavior. Different diagnostic techniques have been adopted for understanding physical condition of the power cables. To detect partial discharges in the insulation of the service aged equipment, various voltage sources and oscillating waves in the range of 50-1000 Hz were used. In past literature experiments on power cables [1,4] and of generators stator [6] were performed and it was found that the partial discharge quantities such as partial discharge extinction voltage, PD level have no fundamental differences obtained due to oscillating voltage waves and 50(60)Hz ac energizing methods .

The field of diagnostics started 1992 at KTH with a project to diagnose Cross-linked Polyethylene cables that suffered by water-trees [7, 8]. The method applied was High Voltage Dielectric Spectroscopy [12] performed in the low frequency range, i.e. from 1 mHz to 1000 Hz. The method of dielectric spectroscopy has also been applied on oil-paper insulated high voltage equipment such as power transformers [10] and oil impregnated paper cables [11]. Partial discharges are measured and analyzed at different frequencies of the applied voltage through the recent developed technique of (VF_PRPDA) [13,14]. At different applied frequencies, the local conditions at defects have been changed due to the frequency dependence

of the partial discharges. From local conditions at defects which is due to the frequency dependence can be utilized for insulation diagnostic purpose.

II. LITERATURE REVIEW

Gafvertl et al have used phase resolved partial discharge variable frequency analysis technique for partial discharge measurements. The variable frequencies were used in place of normal power frequency. It is observed how the frequency dependency is inclined because of the conductivity through insulation and cavity walls. The results obtained with simulation have been compared with measurement results on mica insulated stator bar. We can suggest an analysis on mica insulated bar stator bar through comparing with simulation results. The authors have concluded that with type of modeling they used in this paper are useful to understand variable frequency partial discharge forms [1]. G. Chen et al have also worked on the partial discharge (PD) under variable frequency. However they have focused either on spherical or ellipsoidal as the best common forms of cavities establish in insulation material are of this type. The model presented in this paper can be utilized in a homogenous dielectric to describe the spherical cavity. The developed model is useful to determine the effect of applied frequency on partial discharge action. The authors have concluded that statical time lag and dielectric material time constant play an important role on partial discharge in spherical cavity [2].

Bodega et al have described a method to simulate partial discharge measurements in bounded spherical cavities under the range of 0.1Hz-1000Hz. From the simulation results the information about the impact of frequency on PD process have been derived. They have investigated from both the experimental results and numerical analysis, the voltage frequency have large impact on the Partial discharge behavior. The authors have successfully simulated the partial discharge process with use of numerical analysis based on mathematical model [3]. Morshuis et al have investigated the insulation of the service aged components with the help of very low frequency (VLF).Based on this study the authors have concluded that PD level obtained with above than 200Hz is slightly small than that observed with the 50Hz ac energizing method. However the PD process at lower frequencies can be either very close to that at 50Hz or quite different [4].

III. RESEARCH METHODOLOGY

A. MODEL

Simple test objects are used for measurement of PD under variable frequencies by applying voltage as in figure 1.1. One cylindrical cavity is present in test object in a exfoliate insulation. Insulating plates are passed together in between two electrodes of disc shaped to create the test objects in this way. Brass and cast in epoxy is used to make electrodes in order to prevent discharges at the edges of electrodes. To drill a hole in one or more insulating plate for creating cylindrical cavity. Advantage of using this type of cavity shape is to make it more accurate and easy. And no PD seen in between insulating plates up to 12 kV applied voltage.
Drilled hole diameter changed for varying cavity diameter. By changing insulating plates thickness height of cavity is to be changed.
Rearranging the insulating plates between electrodes, cavity location is to be changed. To create cavities height about 1 mm thickness of insulating plates are taken. In practice cavities are less thick i-e machine insulation. As I mm plates are easy in use.

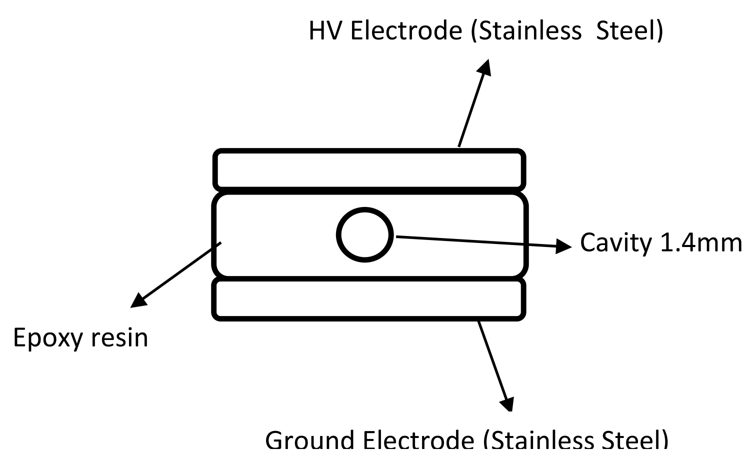
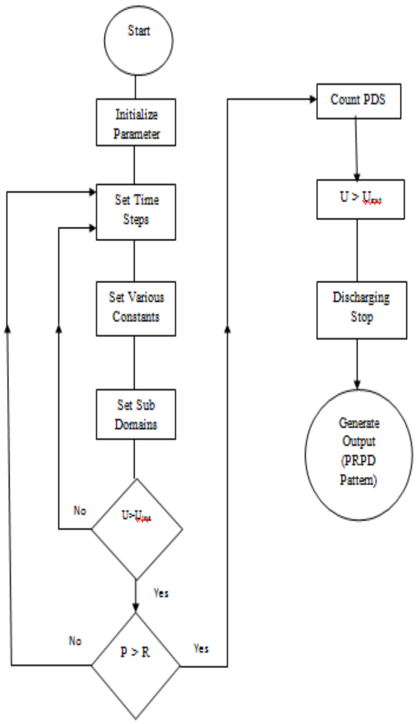


Figure 1: Test object with cylindrical cavity. Cross-section along symmetry axis.

B. FLOW CHART

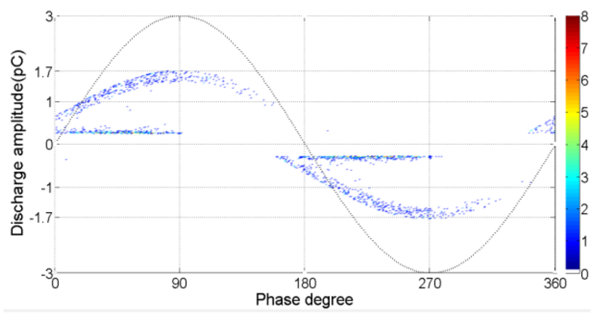


First of all model has been designed in the matlab software. We initialize all the parameters in the designed model. We set the time steps to which model will run. After selecting the time steps, the model geometry parameters have been set. In the next step of model will check the condition that void voltage should be greater than the inception voltage. If the condition is true the program will move to the next condition of probability of electrons should be greater than random number. If both conditions are true then the program will move forward on the other hand if the condition is false the program will back to the time steps to check the condition again. Then the model will count number of partial discharges occurred. After counting number of partial discharges, if void voltage is greater than extinction voltage the discharge will stop. Finally the matlab model will generate the output in the form of phase resolved partial discharge pattern.

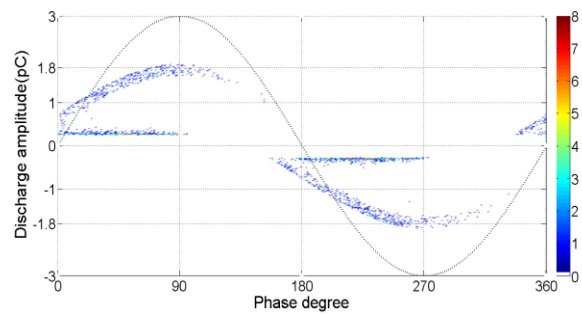
IV SIMULATION RESULTS

a) PRPD PATTERN UNDER VARIOUS APPLIED VOLTAGE AMPLITUDE:

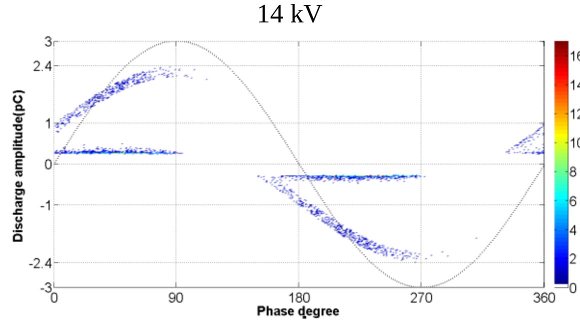
This section illustrates how the PD frequency dependence is influenced by amplitude of the applied voltage. With a diameter of 1.5 mm in an insulated cavity the PD activity is simulated at applied voltage amplitude of 13, 14,15,16,17 and 18 kV. Below the voltage amplitude of 8kv, there were no PDs observed.



13kV



14 kV



15 kV

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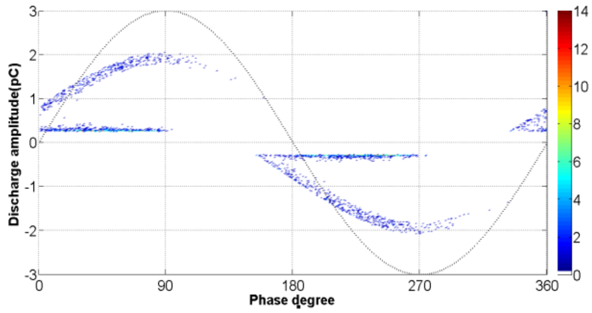
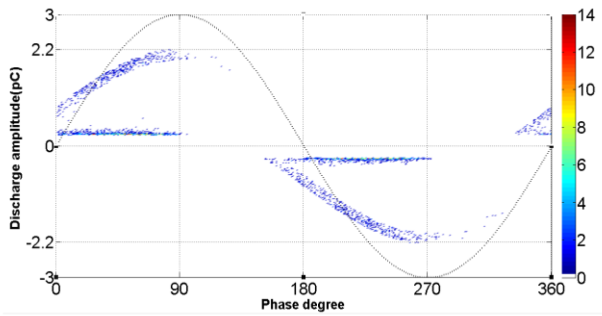
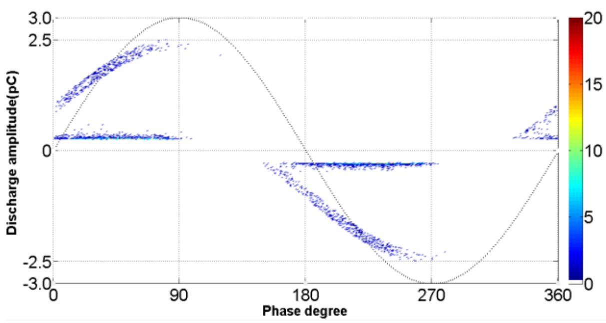


16 kV



17 kV



18 kV

Figure 2: PRPD pattern under various voltgae amplitude.

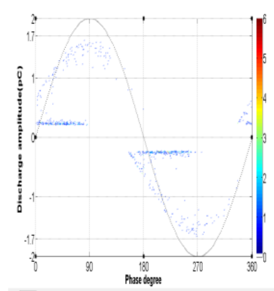
Figure 2 shows the simulated PD patterns at amplitude 13, 14, 15, 16, 17 and 18KV at power frequency with diameter of 1.5mm. The PD activity in the cavity clearly changes with the voltage Amplitude. As the voltage is increased from 13kv-18kv, the maximum PD magnitude increase from about 1700 pC at 13kv to about 2500 pC at 18kv. In contrast the minimum PD magnitude is approximately constant. Hence, there is a wider spread in PD magnitude at higher voltage than at lower voltage.

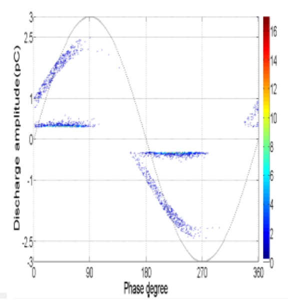
The PD activity is similar with respect to the polarity of applied voltage for an insulated cavity. With the increasing frequency the statical effect was observed with the change in maximum PD magnitude. There was a wide spread in PD magnitude at 50 Hz frequency. The average phase positions of positive PDs at 0.01 Hz and 50 Hz are 105 deg and 140 deg, respectively.

b) PRPD PATTERN UNDER DIFFERENT CAVITY SIZE:

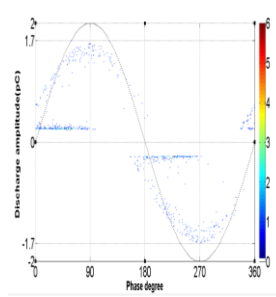
In this section it is described that the cavity diameter can also influence the partial discharge frequency dependence of the test object. With a15 kV applied voltage amplitude and different frequency, the partial discharge activity for insulated cavities of 1.4 mm and 1.6 mm were simulated respectively.

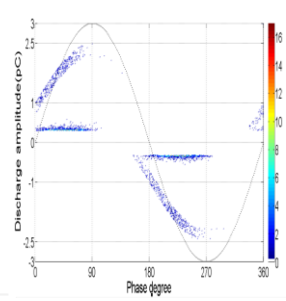
10 kV and 7 kV were the lowest voltage amplitude where partial discharges were observed with a cavity diameter of 1.4 mm and 1.6 mm respectively. It is observed that with a cavity diameter of 1.4 mm, the field enhancement is lower than the cavity diameter of 1.6 mm. Because of that, the partial discharge inception voltage was large with 1.4 mm diameter than 1.6 mm.



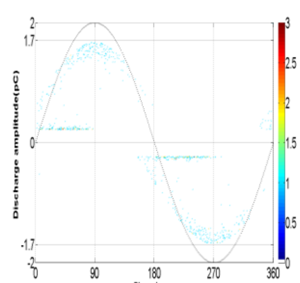


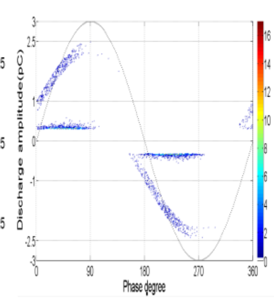
PRPD pattern at 1.4 mm, 50 Hz PRPD pattern at 1.6 mm, 50 Hz





PRPD pattern at 1.4 mm, 35 Hz PRPD pattern at 1.6 mm, 35 Hz





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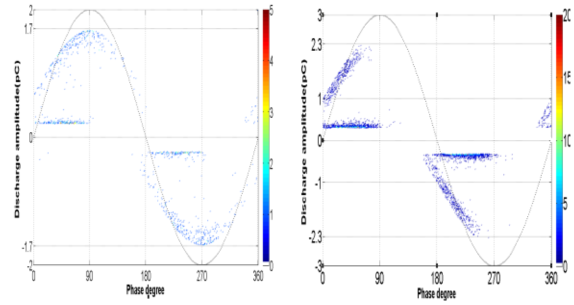
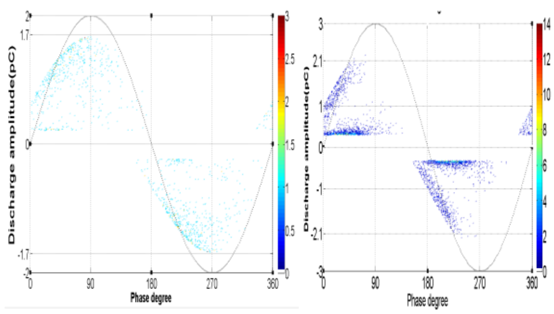
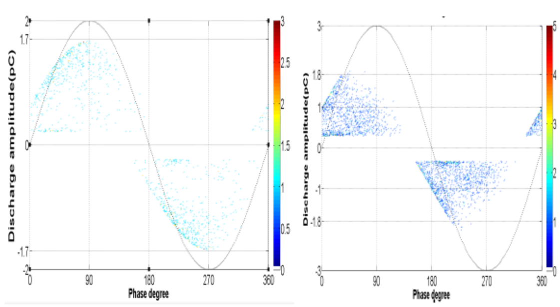
PRPD pattern at 1.4 mm, 25 Hz PRPD pattern at 1.6 mm, 25 Hz



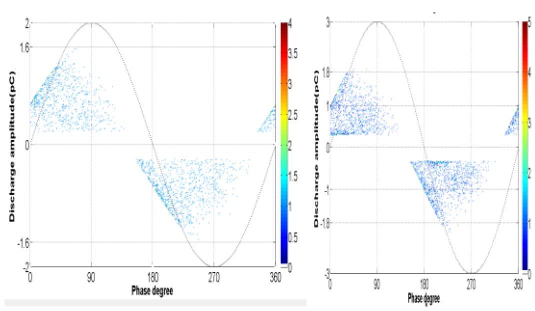
PRPD pattern at 1.4 mm, 15 Hz PRPD pattern at 1.6 mm, 15 Hz



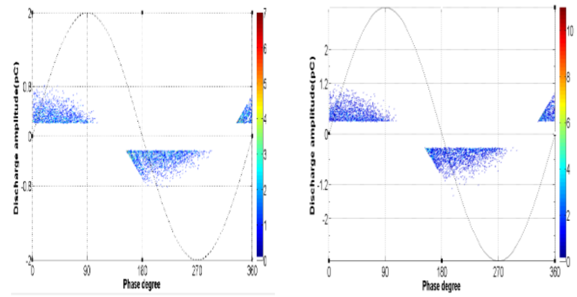
PRPD pattern at 1.4 mm, 10 Hz PRPD pattern at 1.6 mm, 10 Hz



PRPD pattern at 1.4 mm, 5 Hz PRPD pattern at 1.6 mm, 5 Hz



PRPD pattern at 1.4 mm, 1 Hz PRPD pattern at 1.4 mm, 1 Hz



PRPD pattern at 1.4 mm, 0.1 Hz RPD pattern at 1.6 mm, 0.1 Hz

Figure 3: Comparison of PRPD pattern at 1.4 mm and 1.6 mm void diameter 50-0.1 Hz frequencies.

For test objects with varying cavity diameter a comparison of the PD magnitude at a frequency 50-0.1 Hz have been illustrated in Figure. 3. It was observed, there were different partial discharge inception voltages at different cavity diameters of the test objects. The PDs were concentrated to one or more distinct magnitudes for all cavity diameters. This illustrates that the PD activity does not influenced by the statical time lag significantly.

It was also observed that there were concentration of PDs at 0.01 Hz to a magnitude of about 800 pC for all diameters. There was a smaller concentration of PDs above 1200 pC for a diameter 1.6 mm. there was one preferred magnitude for a diameter of 1.4 mm at 50 Hz. It was too noticed that with increasing frequency the actual number of PDs per cycle are higher and increased, since the no. of similar detected partial discharges increased. The test objects with different cavity diameter have difference in PD frequency dependence was due to that the no. of PDs per cycle, whereas magnitude of PD were same.

It was also found that the no. of PDs per cycle was about the same for the smallest cavity diameter at all frequencies. In addition to that the no. of PDs per cycle and the maximum no. of similar detected PDs decreased with decreasing frequency for the largest cavities. Finally it was discovered that test objects with largest cavity diameter have higher no. of PDs because of PD inception voltages decreased with increasing cavity diameter. Also with increasing cavity diameter the no. of similar PD detected increased.

V CONCLUSION

More information about the condition of an insulation system is achieved from simulation of partial discharges at variable frequencies of the applied voltage than from simulation at the single frequency. It becomes possible to differentiate between insulated

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cylindrical cavities of different heights and cavities bounded by an electrode through simulation of partial discharge at variable applied frequency.
Using two dimensional field model, the sequence of partial discharges in insulated cylindrical cavity at different frequencies were simulated. To obtain consistent charge densities and currents in the model the discharges were simulated dynamically. From the two dielectric time constants and statical time lag, the model can be effectively utilized to predict influence on the partial discharge frequency dependence. In this type of modeling, the simulation time is a critical parameter used.

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